

Research Article

Decades of habitat destruction - is there any chance left for the endemic and Critically Endangered *Cyrtodactylus gialaiensis* in Vietnam?

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Abstract

The discovery of the Gia Lai Bent-toed Gecko (*Cyrtodactylus gialaiensis*) on a coffee farm in Chu Se District, Gia Lai Province, raises concerns about its natural habitat, threats, and conservation status. Restricted to a small range of less than 10 km² in Vietnam and occurring outside any protected area in the country, the species was classified as Critically Endangered on the IUCN Red List soon after its description. A recent survey identified a small population of the gecko in Chu Se District, but other potential sites have not been investigated. In this study, we expand the survey area to assess the population status and distribution of this Critically Endangered species. Our results show that *C. gialaiensis* occurs in at least three districts of Gia Lai Province, including Chu Se, Duc Co and Chu Pah. The subpopulation size in Chu Se is estimated to be extremely small, with fewer than 100 individuals, but still larger than those found in Duc Co and Chu Pah. We identify habitat loss, degradation, and fragmentation, as well as uncertainties related to land use and land cover, as the main drivers of its alarming population decline and the potential imminent extinction of its wild population in the near future. Although some conservation actions were implemented as part of this study, there remains an urgent need to strengthen both in situ and ex situ conservation efforts for this highly imperiled species.

Key words: Conservation efforts, extinction risks, Gia Lai Bent-toed Gecko, land use change, population decline

Introduction

Habitat loss, referring to the decline in areas suitable for wildlife, typically occurs alongside habitat fragmentation, which divides continuous habitat into smaller, isolated patches (Pimm and Raven 2000; Wilson et al. 2016). These processes are among the main threats to global biodiversity and are the foremost causes of species extinction (Pimm and Raven 2000; Wilson et al. 2016; Hogue and Breon 2022) because they substantially reduce the effective population size and distribution range of resident species and subsequently disrupt interspecies interactions essential for ecosystem functionality (Haddad et al. 2015; Newbold et al. 2015). While evolutionary advantages associated with habitat fragmentation may occur in some animal populations, this process is often too slow to benefit many species facing ongoing habitat degradation (McClure et al. 2008; Allendorf et al. 2013). Consequently, habitat loss is associated with over 85% of species classified as threatened on the IUCN Red List (Hogue and Breon 2022; IUCN Red List of Threatened Species 2025). Of these, habitat loss has a particularly strong negative effect on reptile populations compared with other vertebrate groups, such as birds and mammals, due to small distributional ranges, high levels of endemism, limited dispersal ability, and specific ecological requirements (Todd et al. 2010; Böhm et al. 2013; Meiri et al. 2018). In addition, Böhm et al. (2013) reported that many reptile species have been adversely impacted by habitat loss in regions with both high (tropical regions) and low reptilian species richness. In particular, Southeast Asia is at the center of this threat due to its extremely high rate of deforestation (Böhm et al. 2013).

Located in Southeast Asia, Vietnam is recognized as one of the most biodiverse countries globally, featuring a wide range of ecosystems, including tropical forests, streams, lagoons, and coral reefs (Myers et al. 2000; Sterling et al. 2006). However, like many tropical regions, Vietnam has experienced dramatic losses of primary forest due to agricultural expansion over recent decades (Nguyen 2000; Meyfroidt and Lambin 2008, 2009; Bourgoin et al. 2019; MARD 2020; Xiao et al. 2023). Between the 1930s and 1992, the nation's forest cover declined substantially from 42.7% to 24.7% of its total land area based on land-cover change analyses (Nguyen 2000; Meyfroidt and Lambin 2008, 2009; MARD 2020). In addition to massive overexploitation, habitat loss has resulted in declines in several reptile populations across the country (van Schingen et al. 2015; Le et al. 2020; Ngo et al. 2022). Since 1992, national reforestation initiatives aimed at rehabilitating barren land have facilitated a recovery in forest cover, which reached approximately 41.89% in 2019 (Fig. 1) (Meyfroidt and Lambin 2009; Bourgoin et al. 2019; MARD 2020). However, reforestation efforts have predominantly focused on industrial plantations composed of fast-growing monocultures of exotic species, such as *Eucalyptus* sp., *Acacia* sp., and *Pinus* sp., or native species, such as *Coffea* sp., *Piper nigrum*, and *Durio zibethinus* (Turnbull et al. 1997; Kha et al. 2003). These monoculture plantations are generally ineffective in restoring original biodiversity (Barlow et al. 2007; Matthews et al. 2002; Newmaster et al. 2011) and cannot replace the conservation value of natural ecosystems. Moreover, plantations consisting of single species are easier to log (Kelty 2006) or convert to other crops, leading to uncertainty in

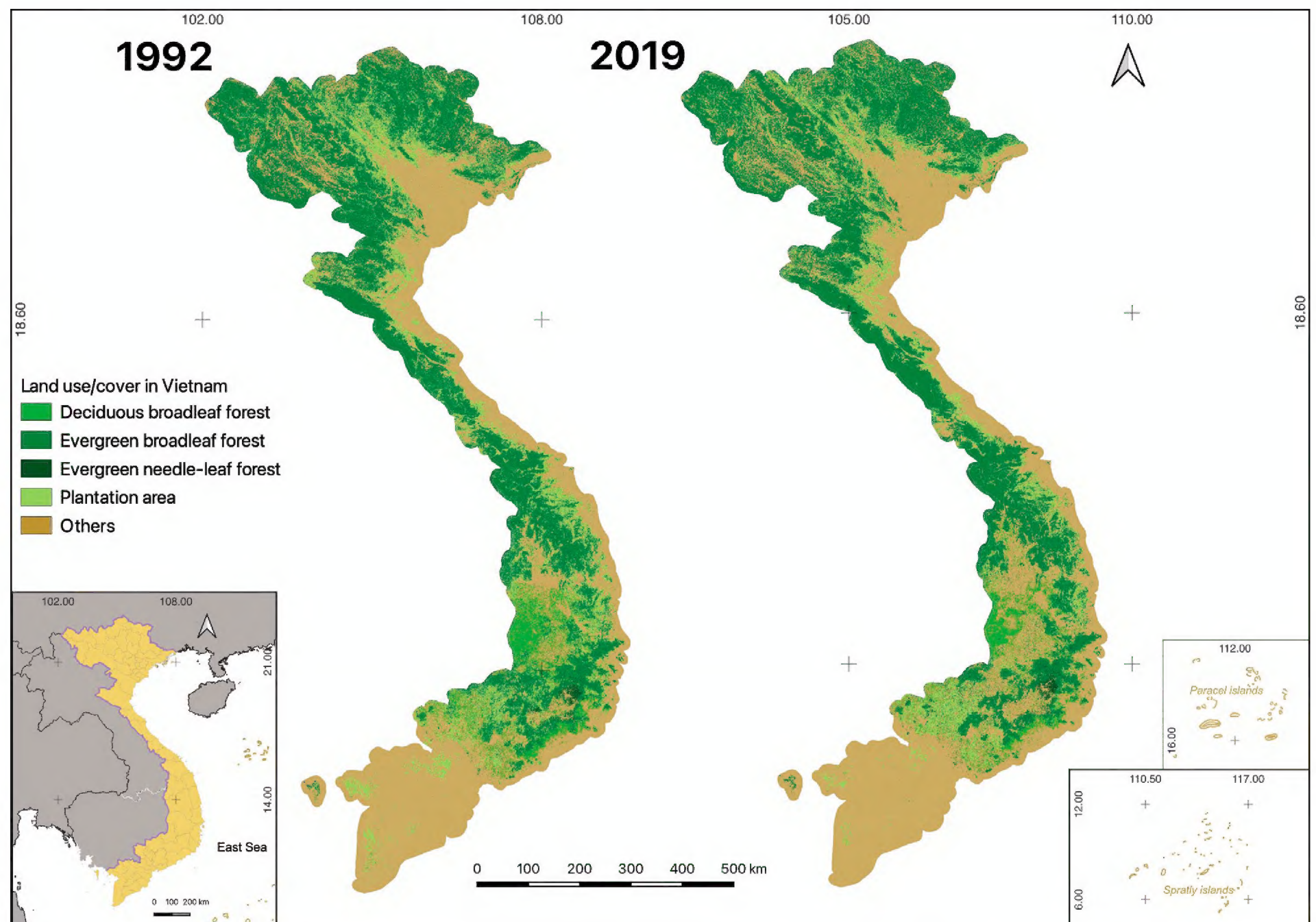


Figure 1. Forest cover change in Vietnam from 1992 to 2019 (map based on ALOS Science Project, Japan Aerospace Exploration Agency).

land use. Species inhabiting plantation areas are therefore generally more susceptible to human disturbance than those living in natural habitats.

The Gia Lai Bent-toed Gecko, *Cyrtodactylus gialaiensis*, was first discovered in 2017 (Luu et al. 2017; Luu 2018; Luu et al. 2020). To date, it has only been recorded from a coffee plantation site and from soil cliffs between coffee and rubber plantations in Chu Se District, Gia Lai Province, Vietnam (Fig. 2) (Luu 2018; Luu et al. 2020). This endemic species is estimated to occur within a very restricted distribution range of less than 10 km², located entirely outside protected areas (Luu 2018; Luu et al. 2020). As a result, *C. gialaiensis* has been classified as Critically Endangered (CR) by the IUCN Red List since 2018 (Luu 2018). The species is currently subject to multiple threats, including habitat loss due to land-use change and the risk of predation by domesticated animals (Luu 2018; Luu et al. 2020). However, recent surveys were conducted only within a limited area around the type locality of *C. gialaiensis* in Chu Se District, Gia Lai Province (Luu 2018; Luu et al. 2020). Other potential areas within Chu Se District, as well as suitable habitats surrounding Chu Se, have not been investigated. To better understand the population status and distribution range of this Critically Endangered gecko, we conducted extensive surveys in surrounding areas and identified the threats facing the species. Based on these findings, conservation measures are proposed to reduce extinction risk and improve species protection.

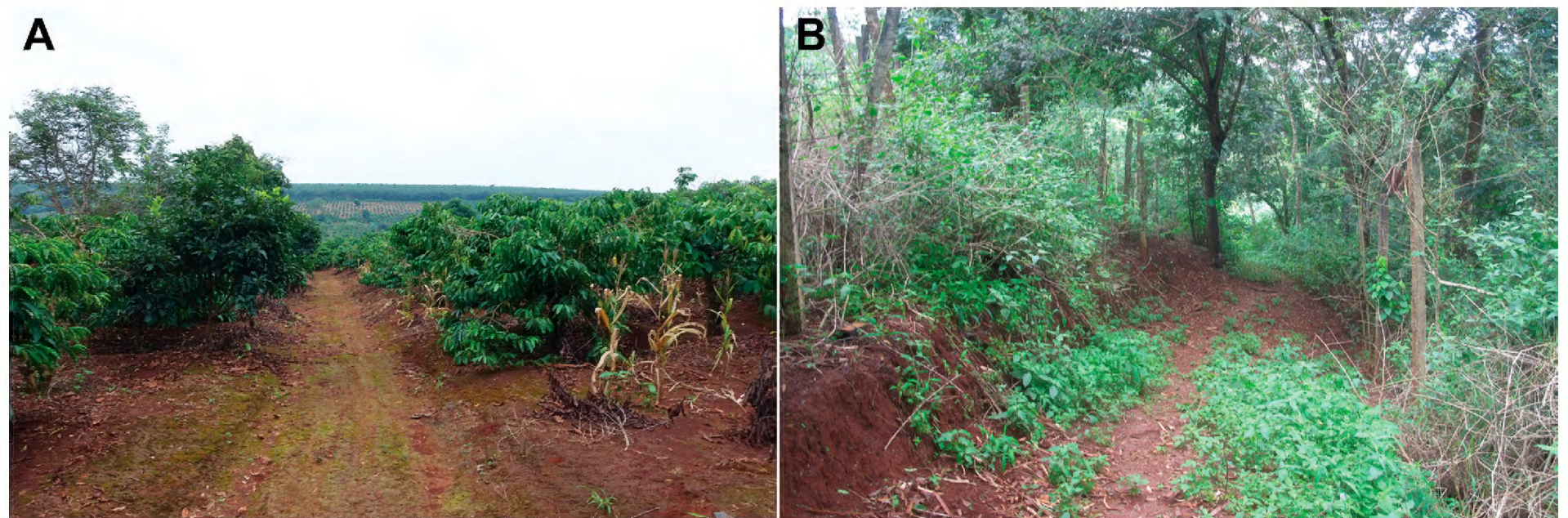


Figure 2. Habitat of *Cyrtodactylus gialaiensis* at the survey site. **A.** Coffee plantation area where *C. gialaiensis* occurs; **B.** Soil cliff near the coffee plantation area.

Materials and methods

Field surveys

Field surveys were carried out in March 2022, October 2022, June 2023, August 2023, July 2024, August 2024, and April 2025 in Chu Se, Duc Co, Chu Pah, and Chu Prong districts, Gia Lai Province. All transects were established based on data published in previous studies (i.e., Luu et al. 2017, 2020; Luu 2018) and direct observations. Each transect was visited three times after sunset, between 19:00 and 00:30 h, when the species is expected to be most active, to ensure the highest detection probability. A total of 28 transects were surveyed in Chu Se (14 transects), Duc Co (five transects), Chu Prong (one transect), and Chu Pah (eight transects), covering coffee, rubber, durian, padauk, passion fruit, and coconut palm plantations. During the surveys, two soil types were also examined, including adobe soils (10 transects in total, with four transects in Duc Co and six transects in Chu Pah) and basalt soils (18 transects in total, with 14 transects in Chu Se, one in Duc Co, one in Chu Prong, and two in Chu Pah). Coordinates of each surveyed transect at the starting and ending points, as well as locations of captured individuals, were recorded using GPS units (Garmin GPSmap62s, WGS84 datum).

Species identification

Molecular data

Due to morphological similarity, distinguishing among members of the genus *Cyrtodactylus* is challenging. To address this issue, molecular identification was used in this study. One or two tail tissue samples were collected from each *Cyrtodactylus* subpopulation. In total, 18 DNA samples were collected from Chu Se (four samples), Duc Co (five samples), and Chu Pah (nine samples) districts and preserved separately in 70% ethanol (Merck, Germany) for DNA extraction. Total DNA was extracted using the QIAamp DNA Mini Kit (Qiagen, Germany) following the manufacturer's instructions. Extracted DNA was amplified using DreamTaq Master Mix (Thermo Fisher Scientific, Lithuania) in a total reaction volume of 21 μ L (10 μ L of Master

Mix, 5 µl of water, 2 µl of each primer at 10 pmol·µL⁻¹, and 2 µl of total DNA). Polymerase chain reaction (PCR) conditions consisted of an initial denaturation at 95 °C for 5 minutes to activate the Taq polymerase, followed by 35 cycles of 95 °C for 30 s, 45 °C for 45 s, and 72 °C for 60 s, with a final extension at 72 °C for 6 minutes. A fragment of the mitochondrial gene NADH dehydrogenase subunit 2 (ND2) was amplified using the primer pair MetF1 (5'-AAGCTTTCGGGCCCATACC-3') and COIR1 (5'-AGRGTGCCAATGTCTTTGTGRTT-3') (Arevalo et al. 1994; Macey et al. 1997). PCR products were visualized by electrophoresis on a 2% agarose gel stained with ethidium bromide. Successful amplifications were purified using the GeneJET PCR Purification Kit (Thermo Fisher Scientific, Lithuania). Purified PCR products were sequenced in both directions by 1st Base (Malaysia). Sequences were then validated using Sequencher v4.10 (Gene Codes, Ann Arbor, MI) with default settings and compared with available data in GenBank using the BLAST tool implemented by the National Center for Biotechnology Information. Newly obtained sequences were deposited in GenBank under accession numbers [PX694330–PX694338](#).

Morphological analysis

Measurements followed Ziegler et al. (2022) and Luu et al. (2017) and were taken using a slide caliper to the nearest 0.1 mm. Measurements were taken on the right side of specimens unless otherwise indicated. Abbreviations are as follows: SVL, snout–vent length, measured from the tip of the snout to the vent; HL, head length, measured from the tip of the snout to the retroarticular process of the jaw; HW, head width, the maximum width of the head; HH, head height, measured from the occiput to the underside of the jaws; OrbD, orbital diameter, the greatest diameter of the orbit; BW, body width, the widest distance of the body; TrunkL, trunk length, the distance from the axilla to the groin, measured from the posterior edge of the forelimb insertion to the anterior edge of the hindlimb insertion; ForeaL, forearm length, measured from the base of the palm to the tip of the elbow; CrusL, or crus length, is measured from the base of the heel to the knee.

Population estimation

Population size was estimated using a capture–mark–recapture method. Each individual was captured by hand, measured to obtain morphological data, and marked once on the head or mid-body using correction fluid pens (Tipp-Ex, Germany). Marks consisted of a series of dots for juveniles (SVL < 47 mm) and numbers for adults (SVL ≥ 47 mm) (Luu et al. 2017) and were used to denote capture history. Individuals were released at the point of capture. A continuous series of dots and numbers was assigned each day. For example, on the first day at transect 1, four individuals were captured and labeled 1 to 4 (adults represented by numbers 1, 2, 3, and 4, and juveniles represented by one to four dots). On the following day, four newly captured adult individuals were labeled 5 to 8.

Each transect was surveyed three times, with intervals of 1 to 2 days between visits. Because no studies have examined the home range of this species,

the home range of *C. gialaiensis* was assumed to be very small (approximately 0.0001 km²), based on data from another gekkonid species, *Gekko japonicus* (Park et al. 2019). Populations were assumed to be closed, with no immigration or emigration, during the 5–7 days of each survey. The Schnabel index method was applied to estimate population size for *C. gialaiensis* (Schnabel 1938). In particular, population size ($\widehat{N}$) was calculated using the following formula:

$$\widehat{N} = \frac{\sum_{i=1}^t (C_i M_i)}{\sum_{i=1}^t R_i}$$

Variance

$$s^2 \left(\frac{1}{\widehat{N}} \right) = \frac{\sum_{i=1}^t R_i}{\left(\sum_{i=1}^t (C_i M_i) \right)^2}$$

Standard error of

$$s_{\bar{x}} \left(\frac{1}{\widehat{N}} \right) = \sqrt{s^2 \left(\frac{1}{\widehat{N}} \right)}$$

Where M_i is the total number of previously marked animals at time i , C_i is the number of animals caught at time i , and R_i is the number of marked animals caught at time i . A 95% confidence interval was also calculated to reduce bias (Crow and Gardner 1959; Krebs 2014) as follows:

$$\text{Lower 95\% confidence limit} = \frac{\sum (C_i M_i)}{\sum R_i}$$

$$\text{Upper 95\% confidence limit} = \frac{\sum (C_i M_i)}{\sum R_i}$$

where the 95% confidence interval for $\sum R_i$ was obtained from the Poisson distribution. In addition, population densities of *C. gialaiensis* (adults only) were also calculated per square kilometer (indiv./km²) for each surveyed transect and per day (indiv./km²/day).

Microhabitat assessment

Regarding microclimatic parameters, air temperature (°C) and relative air humidity (%) were measured using a digital thermometer (TFA Dostmann/Wertheim, Cat. No. 30.5015, Germany) at each location at a height of 0–1 m from the animals. A Mestek digital infrared thermometer pyrometer laser (Mestek, China) was also used to measure temperatures (°C) at the substrate surface and on the body surface of animals (belly). The mean and standard error of the mean for morphometric measurements and microhabitat characteristics were calculated using R v4.4.2 (R Core Team 2025).

Threat identification

The effects of human activities on the species were recorded during field surveys. This study did not apply a formal or quantitative method to evaluate these threats.

Results

Species identification

We successfully sequenced a fragment of the ND2 gene from a total of 18 samples. Of these, 11 samples collected from Chu Se (two samples), Duc Co (five samples), and Chu Pah (four samples) showed 98.62–99.22% sequence similarity to the holotype sequence of *C. gialaiensis* (GenBank accession number [MT953497](#); voucher number VNUF R.2017.1). The remaining seven sequences, all originating from Chu Pah, were identified as belonging to a different species. However, because only one or two individuals were encountered per night across multiple transects in Duc Co and Chu Pah, data from four transects in Chu Se District were selected for analyses of morphometric measurements, microhabitat characteristics, and population size estimation. Morphometric measurements of the surveyed subpopulations fell within the range reported for the holotype and paratypes of *C. gialaiensis* (Table 1).

Species distribution and new records

According to our surveys, *C. gialaiensis* was active during both the wet and dry seasons. The species was detected on both basalt and adobe soil types. Our findings further show that *C. gialaiensis* occurs not only in Chu Se District but also in Duc Co and Chu Pah districts, representing the first records of the species from these localities.

Population status

A total of 56 individuals were captured, and 17 recapture events occurred across four transects (transects 1–4). Based on the calculated Schnabel index, the total population of *C. gialaiensis* in Chu Se District was estimated to comprise approximately 96 individuals, with a 95% confidence interval ranging from 40 to 314 individuals, of which only 47 were considered adults (Table 2). The highest density of *C. gialaiensis* was recorded in transect 4 (eight individuals per km²), whereas the lowest density was observed in transect 3 (four individuals per km²). In terms of population recruitment, a low proportion of juveniles (16.98%) was recorded.

Table 1. Morphometric measurements taken from adult samples of *Cyrtodactylus gialaiensis*.

Measurements	Min – max (Transect 1) (n = 8 ind.)	Min – max (Transect 2) (n = 16 ind.)	Min – max (Transect 3) (n = 11 ind.)	Min – max (Transect 4) (n = 9 ind.)	Min – max (n = 3) (Luu et al. 2017)
SVL	53.3–67.3	61.4–73.7	47.9–77.0	59.2–77.7	56.3–62.8
HL/SVL	0.27–0.30	0.23–0.31	0.26–0.31	0.26–0.30	0.28–0.30
HW/SVL	0.19–0.21	0.19–0.23	0.18–0.23	0.19–0.21	0.20–0.21
HH/SVL	0.10–0.13	0.10–0.13	0.11–0.14	0.11–0.14	0.12–0.15
OrbD/SVL	0.05–0.07	0.05–0.07	0.05–0.07	0.05–0.06	0.07–0.08
TrunkL/SVL	0.38–0.57	0.43–0.56	0.45–0.53	0.44–0.50	0.44–0.49
ForeaL/SVL	0.14–0.16	0.13–0.17	0.14–0.16	0.14–0.16	0.15–0.19
CrusL/SVL	0.16–0.18	0.16–0.20	0.15–0.19	0.17–0.19	0.17–0.20

Table 2. Total number of observed individuals, estimated population size, and abundance of observed *Cyrtodactylus gialaiensis* in Chu Se District; DA = density estimate of adult individuals per km², DAD = density estimate of adult individuals per km² per day, D = overall density estimate, DD = overall density estimate per km² per day, N = estimated total number of individuals.

Transects	Transect 1	Transect 2	Transect 3	Transect 4	Total
Oct – 22					
Total Adults	8	19	11	9	47
Total Obs	12	21	13	10	56
Area (km ²)	2.90	2.90	3.3	1.23	9.10
DA (Adults/km ²)	2.76	6.55	3.33	7.32	5.16
DAD (Adults/km ² /day)	0.92	2.18	1.11	2.44	1.72
D (ind./km ²)	4.14	7.24	3.94	8.13	6.15
DD (ind./km ² /day)	1.38	2.41	0.98	2.71	1.54
N – Total Schnabel	19	21	23	23	96

Microhabitat characteristics

Cyrtodactylus gialaiensis was most active between 20:00 h and 22:00 h (Fig. 3). Individuals were observed in hole cliffs (Fig. 4A), soil cliffs, on tree trunks and shrubs between coffee plantations and roads (Fig. 4B, C), and within coffee plantation areas (Fig. 4D), at elevations ranging from 557 to 650 m a.s.l. The species was found in areas characterized by relatively low temperatures and high humidity. Across the four survey sites, mean air temperature was 23.00 ± 0.14 °C (n = 71; Table 3), with mean relative humidity of 81.42 ± 1.01% (n = 71; Table 3). Mean canopy cover was 35.00 ± 5.09% (n = 71; Table 3), and heights ranged from 0 to 250 cm above ground level (mean = 41.69 ± 6.24 cm; n = 71). The species was detected on substrates with relatively low temperatures (mean = 21.63 ± 0.16 °C; n = 57), and mean body temperature was 22.09 ± 0.14 °C (n = 69; Table 3).

Main threats

Among all recorded threats, habitat loss due to land-use change represents the most critical risk to all populations of *C. gialaiensis*. During surveys conducted in two different seasons, most individuals of *C. gialaiensis* were found inside coffee

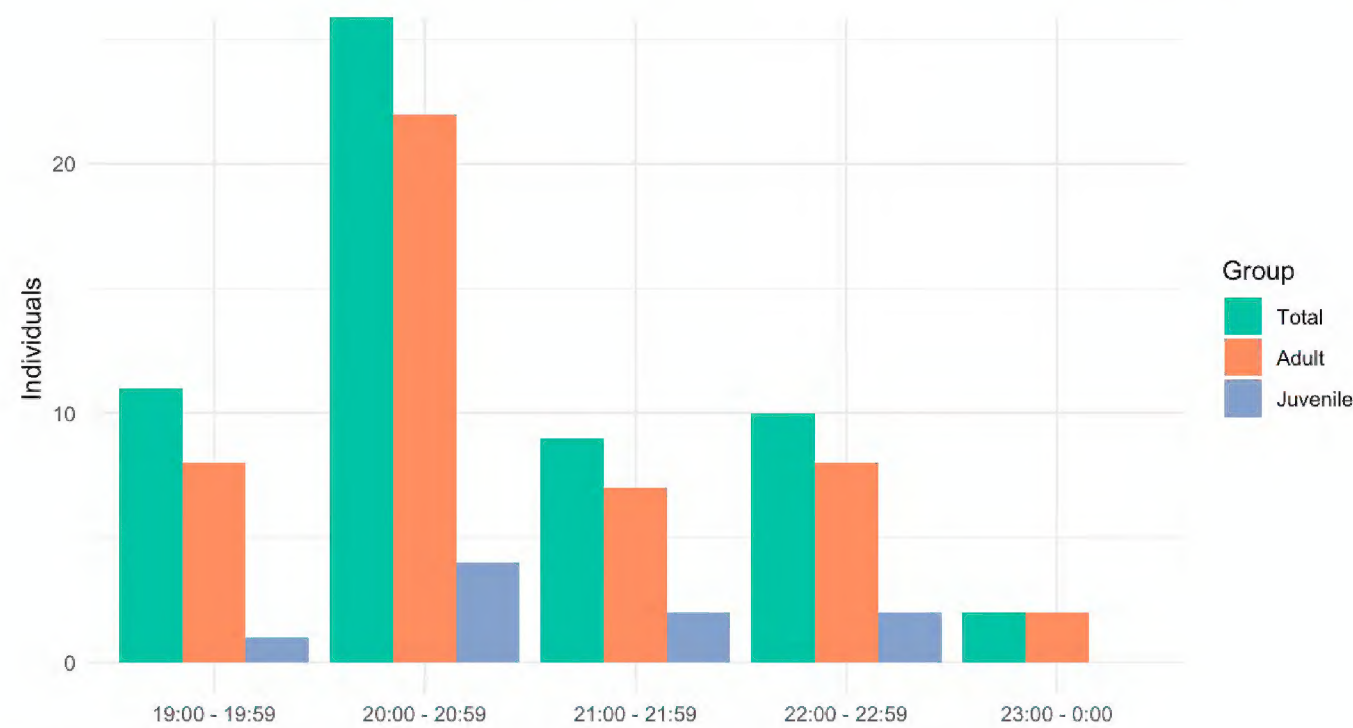


Figure 3. Activity period of *Cyrtodactylus gialaiensis* (n = 68) during the survey period.



Figure 4. *Cyrtodactylus gialaiensis* in the wild. **A.** Adult inside a small hole cliff; **B.** Adult on a soil cliff; **C.** Adult on a tree trunk; **D.** Adult on a coffee stump.

Table 3. Microhabitat characteristics of *Cyrtodactylus gialaiensis*.

Transects	Number of observations	Min – Max	Mean $\pm$ SE
Humidity [%]	56	74–95	84.79 $\pm$ 0.81
Air temperature [°C]	56	20.3–25.6	23.13 $\pm$ 0.14
Substrate temperature [°C]	56	19.3–24.2	21.65 $\pm$ 0.16
Animal temperature [°C]	56	19.8–24.8	22.22 $\pm$ 0.15
Canopy coverage [%]	56	0–100	40.27 $\pm$ 6.24
Distance to ground	56	0–250	52.76 $\pm$ 7.22

plantations or in areas between coffee plantations and local roads. A small subset of the population continued to inhabit isolated patches of natural vegetation, primarily consisting of shrubs and small native trees. However, all of these sub-populations face uncertainty related to land-use change driven by landowners’ profit motives. For example, during our visit in October 2022, we documented a shift in land use from bamboo to coconut palm plantations at site T2. Changes in plantation type can result in unsuitable habitats for the species and may also increase levels of chemical pollutants that adversely affect local populations.

Furthermore, none of the studied populations were located within existing protected areas, rendering them particularly vulnerable to land conversion activities (Fig. 5A, B). Large amounts of garbage, including plastics and chemical products, were also observed around the species’ habitat in Chu Se (Fig. 5C–F). In addition, a relatively high proportion of individuals exhibiting regenerated



Figure 5. Threats to the population of *Cyrtodactylus gialaiensis*. **A, B.** Land-use change; **C–F.** Plastic waste in the habitat of *C. gialaiensis*.

tails was recorded across surveyed locations. Specifically, records of tail condition across four transects in Chu Se indicated that 58.33%, 50%, 38.46%, and 60% of encountered individuals had regenerated tails, respectively.

Discussion

Gia Lai is the second-largest province in Vietnam, covering an area of approximately 15,000 km² (Le et al. 2024; People’s Committee of Gia Lai Province 2025). It plays an important role in socioeconomic development in the Central Highlands, which has resulted in multiple challenges related to land resource

management. A comparative analysis of forest cover between 1992 and 2019, based on forest cover maps derived from databases managed by the ALOS Science Project, Japan Aerospace Exploration Agency, indicates that deforestation, afforestation, agricultural expansion, and urbanization, along with other extensive development activities, have substantially contributed to the deterioration of natural forests (Fig. 6) (ALOS Science Project, Japan Aerospace Exploration Agency). In addition, strategies aimed at converting traditional crops to high-value crops and adapting to climate change during the period from 2023 to 2025, with a vision toward 2030, were proposed in 2023. These strategies recommend replacing unproductive crops, such as rubber, pepper, coffee, and sugarcane, with more economically viable plants, including passion fruit, potato, pineapple, banana, chili, watermelon, and soybean (Law Library 2023). This transition represents a major short- and medium-term threat to wildlife survival (Sala et al. 2000; Quesada et al. 2009; Mas et al. 2010).

The distribution of *C. gialaiensis*, as confirmed by both morphological and molecular evidence, is documented in three districts of Gia Lai Province, namely Chu Se, Duc Co, and Chu Pah. Distances between the nearest subpopulations are 22 km between Chu Se and Duc Co, 41 km between Duc Co and Chu Pah, and 56 km between Chu Pah and Chu Se, based on Google Earth Pro v7.3.6.10201 (64-bit) (13 January 2025). These data suggest that *C. gialaiensis* may have had a more extensive distribution across Gia Lai Province in the past. However, the species was not detected in 16 of the 28 surveyed transects. In addition, the rarity of *C. gialaiensis* at other locations indicates that much of its suitable habitat has been lost and that the species

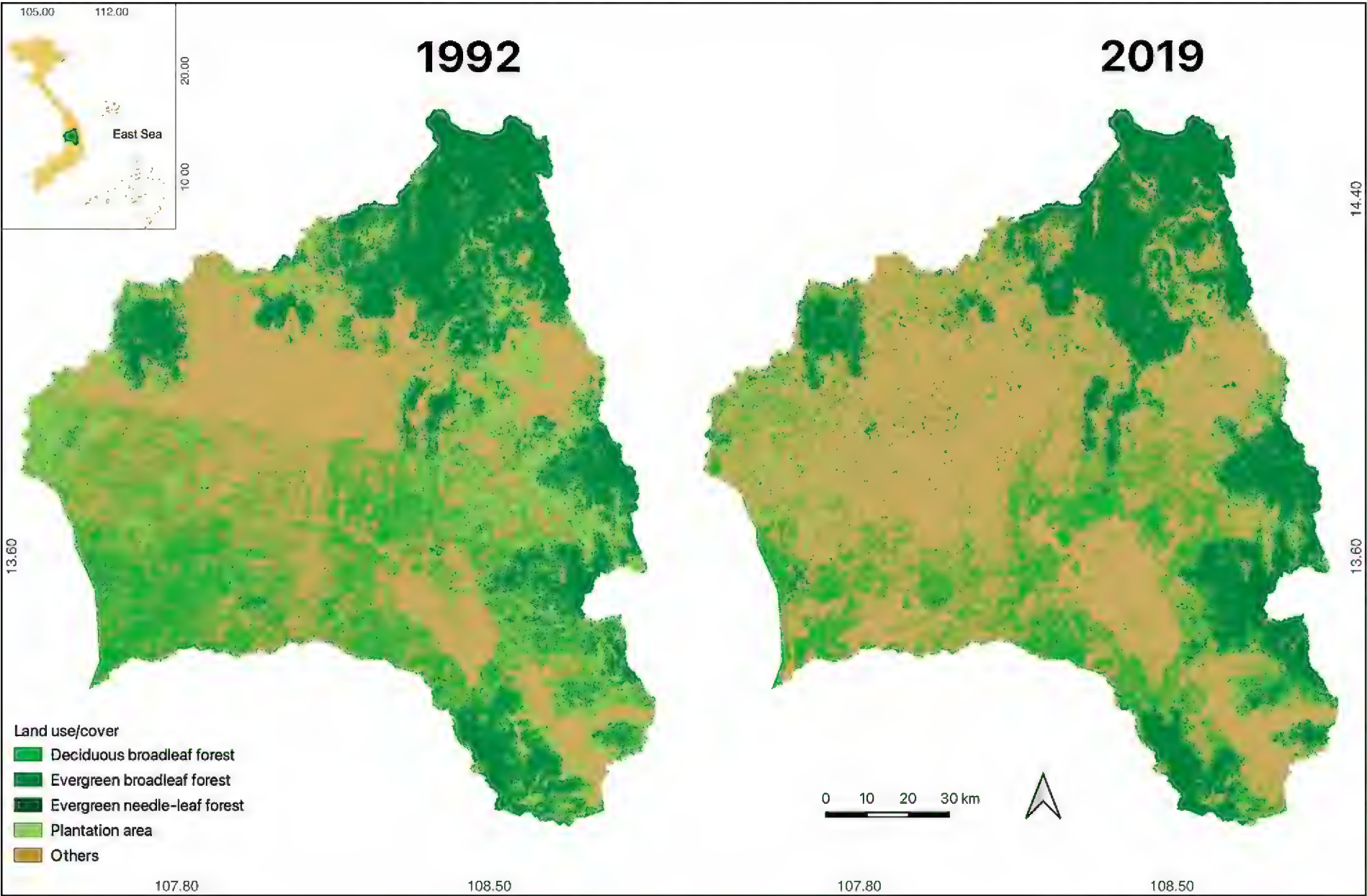


Figure 6. Land-use change in Gia Lai Province from 1992 to 2019.

can persist only in remnant patches of natural vegetation or has been forced to adapt inadvertently to monoculture plantations, such as coffee and rubber (Luu 2018; Luu et al. 2020). There is an urgent need for the formulation of effective conservation measures to avert its imminent extinction.

Population size is a critical determinant of wildlife survival, with species that have limited distributions being especially vulnerable (Foufopoulos and Ives 1999; Reed et al. 2003; van Schingen et al. 2014). Therefore, obtaining accurate information on population size should be prioritized in conservation planning (Shaffer et al. 2002). According to Reed et al. (2003), an effective population size (N_e) of at least 7,000 individuals is required to ensure the long-term survival of any vertebrate species. In contrast, classical recommendations and recent simulation results suggest an N_e of 500 individuals for species with moderate reproductive rates (Franklin 1980; Pérez-Pereira et al. 2022). For *C. gialaiensis*, our preliminary assessment estimates approximately 96 individuals in Chu Se District, with even fewer individuals documented in Duc Co and Chu Pah districts. These values are far below recommended minimum viable population thresholds, making the species particularly vulnerable to environmental and demographic stochasticity.

Furthermore, our surveys indicate that migration among subpopulations is unlikely because of the long distances separating them and the absence of suitable habitat corridors connecting the metapopulations. Over the long term, habitat loss and fragmentation may reduce genetic diversity and increase the risks of genetic drift and inbreeding depression, potentially leading to higher extinction vulnerability of these subpopulations (Levins 1969; Hanski and Gilpin 1997). When combined with additional threats, such as climate change and disease, it is evident that *C. gialaiensis* requires immediate conservation action, particularly because its distribution range lies entirely outside the national protected area network.

Luu (2018) assessed the conservation status of the species and classified it as Critically Endangered (B1ab(iii)+2ab(iii)). This assessment was based on an estimated extent of occurrence (EOO) and area of occupancy (AOO) of less than 10 km² and the fact that the species was known from a single location. In addition, a continuing decline was observed, estimated, inferred, or projected in the area, extent, and or quality of habitat. In contrast, the Vietnam Red Data Book revised the conservation status of the species and downgraded it to Endangered (B1ab(iii)). This classification was based on an estimated EOO of less than 5,000 km², with the species' range either being severely fragmented or known from a single location, as well as a continuing decline in habitat area, extent, or quality (Nguyen et al. 2024). Using all recorded localities, we recalculated the EOO and AOO with the GeoCAT tool (GeoCAT Tool 2025) developed for the IUCN Red List (Red List Technical Working Group). The estimated EOO for *C. gialaiensis* is approximately 2,124 km², whereas the AOO is estimated at 56 km². However, despite being recorded in three districts of Gia Lai Province, all subpopulations are estimated to comprise fewer than 50 mature individuals and are highly fragmented. Moreover, we anticipate that the population of *C. gialaiensis* will continue to decline in the coming years due to land-use uncertainty and increasing use of chemical products. Consequently, *C. gialaiensis* meets the criteria for the Critically Endangered category C2a(i) (IUCN Standards and Petitions Committee 2025).

Conclusion

Our surveys revealed that the distribution range of *C. gialaiensis* extends from Chu Se District to Duc Co and Chu Pah districts (Fig. 7). Nevertheless, the species occurs in very low numbers on both adobe and basalt soils and is severely affected by habitat fragmentation and degradation resulting from land-use change. To safeguard habitat at the type locality, a payment for ecosystem services scheme has been implemented in recent years. Under this scheme, the landowner agreed not to use chemical products, convert the coffee plantation to other crops, or conduct activities potentially harmful to the species. According to our results, *C. gialaiensis* occurs not only within plantation areas but also in narrow strips of natural vegetation adjacent to farms. However, none of these sites is located within a protected area. We strongly recommend that additional field surveys be conducted to identify areas with better vegetation

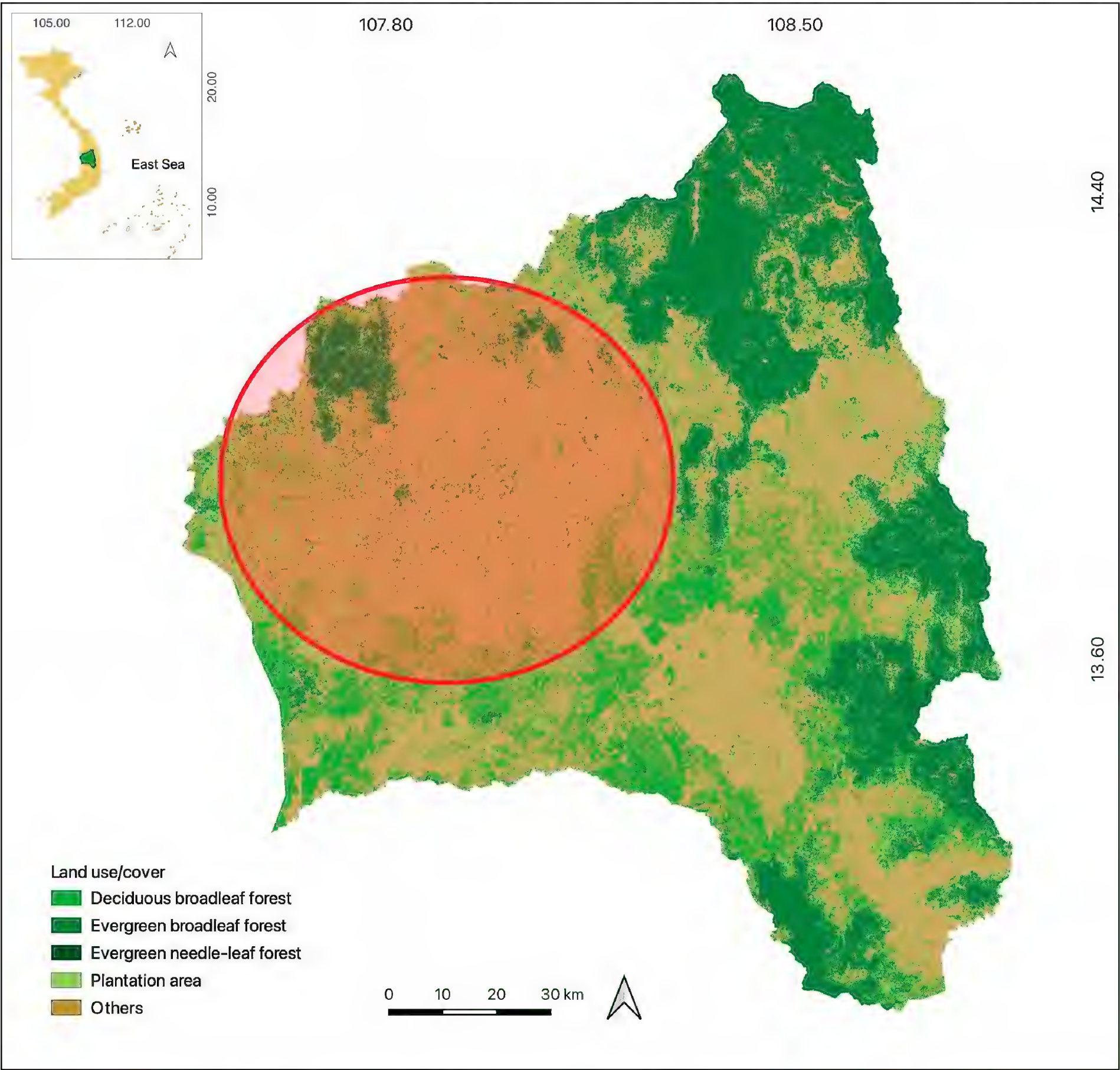


Figure 7. Geographic distribution of *Cyrtodactylus gialaiensis* in Gia Lai Province, shown by red circles.

cover, where suitable sites could be designated as protected areas or species conservation areas to ensure the long-term survival of the species. In addition, a captive-breeding program should be initiated to reinforce the small and fragmented wild populations in the near future.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

The animal study protocol was approved by the Institutional Review Board of the Center for Environment and Community Assets Development (approval date: 7 October 2021; reference number CEPF-111890).

Use of AI

No use of AI was reported.

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Author contributions

Conceptualization, M.D.L, T.Z. T.Q.N., and H.T.N.; methodology, H.T.N., Q.H.D., T.Q.P., H.N.N., H.Q.N., C.T.P., A.T.N.H., T.H.N; software, H.T.N., H.N.N.; validation, H.N.N., H.T.N and M.D.L.; formal analysis, H.T.N., H.N.N.; investigation, H.T.N., H.N.N., M.D.L.; resources, V.Q.L., T.H.N.; data curation, H.T.N.; writing—original draft preparation, H.T.N, M.D.L.; writing—review and editing, H.T.N., M.D.L.; visualization, H.T.N., H.N.N.; supervision, M.D.L.; project administration, M.D.L, T.Z.; funding acquisition, M.D.L., T.Z. All authors have read and agreed to the published version of the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text.

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